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Phenomenology of relic neutralinos is analyzed in an effective supersymmetric scheme at the electroweak scale. It is shown that current direct experiments for WIMPs, when interpreted in terms of relic neutralinos, are indeed probing regions of supersymmetric parameter space compatible with all present experimental bounds.

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1 Introduction

Interest for supersymmetric relics leans on the following properties: i) if R-parity is conserved, the Lightest Supersymmetric Particle (LSP) is stable; ii) if colourless and uncharged, the LSP is a nice realization of a relic Weakly Interacting Massive Particle (WIMP) [1]. In the present paper we assume that supersymmetry exists in Nature and that properties (i) and (ii) hold. Thus the LSP will be our relic WIMP candidate; actually, after some preliminary considerations, our attention will be mainly devoted to the case when the LSP is provided by the neutralino.

In Sect. 2 we discuss some generic connections between WIMP relic abundance and event rates for direct and indirect WIMP detection. Sect. 3 is devoted to a presentation of supersymmetric schemes. Numerical results and conclusions are finally presented in Sect. 4.

2 Relic abundance and detection rates

When we investigate a WIMP as a relic in the Universe, the two most crucial questions are: a) does it contribute in a significant way to the matter content in the Universe, b) is it detectable either directly or through indirect signals?

For a given WIMP, its cosmological relevance and its detectability are related, but in a way which is somewhat different from what one might naively believe. Actually, it turns out that, in the framework which is usually employed for the WIMP decoupling from the primordial plasma, WIMPs with highest detection rates might have a relatively modest relic abundance. For a detailed discussion of these features we refer to Ref. [2]; here we simply sketch the main points.

For definiteness, our discussion is formulated in terms of relic neutralinos, though many features apply to a larger class of WIMP candidates, provided they share with the neutralino the property of having an elastic scalar cross-section off nuclei dominated by a coherent contribution in the range of relevance for current experiments.

Under this circumstance, the detection rate R in WIMP direct measurements is proportional to the product $\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}$, where ρ_χ is the neutralino local density and $\sigma_{\text{scalar}}^{(\text{nucleon})}$ is the neutralino-nucleon cross-section.

The values to be assigned to the neutralino local density $\rho_\chi = \xi \cdot \rho_l$ have to be consistent with the values of the neutralino relic abundance $\Omega_\chi h^2$. When $\Omega_\chi h^2 \geq (\Omega_m h^2)_{\min}$, where $(\Omega_m h^2)_{\min}$ is the minimum value of $\Omega_m h^2$ compatible with halo properties, we simply set $\rho_\chi = \rho_l$ (i.e., $\xi = 1$). When $\Omega_\chi h^2 < (\Omega_m h^2)_{\min}$, the neutralino cannot be the unique cold dark matter particle, thus we assign to the neutralino a *rescaled* local density $\rho_\chi = \rho_l \times \Omega_\chi h^2 / (\Omega_m h^2)_{\min}$ (i.e., $\xi = \Omega_\chi h^2 / (\Omega_m h^2)_{\min}$) [3].

Taking into account these rescaling properties of the local density, we find that R behaves as follows

$$R \propto \sigma_{\text{scalar}}^{(\text{nucleon})}, \quad \text{when } \Omega_\chi h^2 \geq (\Omega_m h^2)_{\text{min}} \quad (1)$$

$$R \propto \frac{\Omega_\chi h^2}{(\Omega_m h^2)_{\text{min}}} \sigma_{\text{scalar}}^{(\text{nucleon})} \propto \frac{\sigma_{\text{scalar}}^{(\text{nucleon})}}{\langle \sigma_{\text{ann}} v \rangle}, \quad \text{when } \Omega_\chi h^2 < (\Omega_m h^2)_{\text{min}}, \quad (2)$$

where σ_{ann} and v are the neutralino–neutralino annihilation cross-section and the relative velocity, respectively. $\langle \sigma_{\text{ann}} v \rangle$ denotes the thermal average of the product $(\sigma_{\text{ann}} \cdot v)$ integrated from the freeze-out temperature to the present-day one. In writing Eqs. (1–2), we used the fact that in the standard scheme for the decoupling of a WIMP from the primordial plasma one has $\Omega_\chi h^2 \propto \langle \sigma_{\text{ann}} v \rangle^{-1}$.

Now, the cross sections $\sigma_{\text{scalar}}^{(\text{nucleon})}$ and σ_{ann} , as functions of any generic coupling parameter ζ , behave similarly (*i.e.* they usually both decrease or increase in terms of variations of this parameter), because of crossing symmetry. Thus, for instance, $\sigma_{\text{scalar}}^{(\text{nucleon})}$ and σ_{ann} are both increasing functions of $\tan \beta$ (see later on for definition), when the relevant processes are mediated by Higgs bosons. Usually, $\sigma_{\text{scalar}}^{(\text{nucleon})}$ increases somewhat faster than σ_{ann} , or approximately at the same rate. Thus, due to the properties displayed in Eqs. (1–2), the typical behaviour of the rate R may be summarized as follows: i) for small values of ζ , both $\sigma_{\text{scalar}}^{(\text{nucleon})}$ and σ_{ann} are small (and then $\Omega_\chi h^2$ is large) and R grows proportionally to $\sigma_{\text{scalar}}^{(\text{nucleon})}$, ii) as the strength of the coupling increases, in the region beyond the value ζ_r (at which $\Omega_\chi h^2 = (\Omega_m h^2)_{\text{min}}$), Eq. (2) applies: the rate R still increases (though less rapidly than before rescaling), or remains approximately flat. This behaviour obtains up to values of the relic densities which fall short of the cosmological interesting range by a couple of decades. The features just discussed for the WIMP direct detection also apply to the indirect experiments consisting in detecting a neutrino flux arriving from the Sun or from the center of the Earth, due to possible WIMP pair annihilations in these two celestial bodies. Indeed, the size of these neutrino fluxes depends on the product $\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}$.

On the basis of the previous arguments, we can conclude that, in the cases of direct detection and indirect detection through pair annihilation in celestial bodies, the detectability of relic neutralinos is usually favoured for neutralinos of small $\Omega_\chi h^2$, *i.e.* for neutralinos which comprise only a subdominant dark matter component.

Therefore, when one explores the possibility of detecting a specific kind of WIMP, it would be self-defeating to restrict the analysis to the case when the putative WIMP contributes dominantly to the matter content in the Universe. Because of this fact, at variance with many analyses by other authors, our scanning of the susy parameter space will also include configurations entailing small neutralino relic abundances. Obviously, among the different situations which one may find in the course of the investigation, the case when the WIMP candidate is both detectable and of cosmological interest will represent the most rewarding occurrence. In the last section, we show that, indeed, a number of neutralino configurations of cosmological interest, though disfavoured by the previous arguments, may reach the level of detectability by current experiments.

In Ref. [2] it is shown that for processes depending on pair-annihilation in the halo the maximal rates occur for values of the relic abundance around the value $(\Omega_m h^2)_{min}$. Subdominant neutralinos are disfavoured for detectability by this type of signals as compared to neutralinos with a relic abundance around the value $\Omega_\chi h^2 \simeq (\Omega_m h^2)_{min}$.

3 Which model for supersymmetry?

Supersymmetry, though strongly motivated by theoretical arguments, is not yet sustained by experimental evidence. Only some possible hints are available: unification of the Standard Model (SM) coupling constants at a Grand Unification (GUT) scale [4], Higgs events at LEP2 [5, 6, 7, 8, 9], fit of precision electroweak data improved by susy effects [10].

However, in the following we assume that supersymmetry exists in Nature and that R-parity is conserved (thus the LSP is stable). The nature of the LSP depends on the susy-breaking mechanism and on the specific regions of the susy parameter space. We consider here gravity-mediated schemes, and domains of the parameter space where the LSP is the neutralino. Extensive calculations on relic neutralino phenomenology in gravity-mediated models have been performed (among the most recent references see, for instance, [11, 12, 13, 14, 15, 16, 17]).

Here we refer to an analysis which we performed in the Minimal Supersymmetric extension of the Standard Model (MSSM) in a variety of different schemes, from those based on universal or non-universal supergravity, with susy parameters defined at the grand unification scale (GUT), to an effective supersymmetric model defined at the Electro-Weak (EW) scale.

3.1 Universal and non-universal SUGRA

The essential elements of the MSSM are described by a Yang-Mills Lagrangian, the superpotential, which contains all the Yukawa interactions between the standard and supersymmetric fields, and by the soft-breaking Lagrangian, which models the breaking of supersymmetry. The Yukawa interactions are described by the parameters h , which are related to the masses of the standard fermions by the usual expressions, *e.g.*, $m_t = h^t v_2$, $m_b = h^b v_1$, where v_i are the *vev*'s of the two Higgs fields, H_1 and H_2 . Implementation of this model within a supergravity scheme leads naturally to a set of unification assumptions at a Grand Unification (GUT) scale, M_{GUT} : i) Unification of the gaugino masses: $M_i(M_{GUT}) \equiv m_{1/2}$, ii) Universality of the scalar masses with a common mass denoted by m_0 : $m_i(M_{GUT}) \equiv m_0$, iii) Universality of the trilinear scalar couplings: $A^l(M_{GUT}) = A^d(M_{GUT}) = A^u(M_{GUT}) \equiv A_0 m_0$.

This scheme is denoted here as universal SUGRA (or simply SUGRA). The relevant parameters of the model at the electro-weak (EW) scale are obtained from their corresponding values at the M_{GUT} scale by running these down according to the renormalization

group equations (RGE). By requiring that the electroweak symmetry breaking is induced radiatively by the soft supersymmetry breaking, one finally reduces the model parameters to five: $m_{1/2}, m_0, A_0, \tan\beta(\equiv v_2/v_1)$ and $\text{sign } \mu$.

We remark that in this very strict scheme the phenomenology of relic neutralinos is very sensitive on the way in which various constraints (for instance those on the bottom quark mass, m_b , on the top quark mass, m_t , and on the strong coupling α_s) are implemented.

Models with unification conditions at the GUT scale represent an appealing scenario; however, some of the assumptions listed above, particularly ii) and iii), are not very solid, because, as was already emphasized some time ago [18], universality might occur at a scale higher than $M_{GUT} \sim 10^{16}$ GeV, *e.g.*, at the Planck scale.

An empirical way of taking into account the uncertainty in the unification scale consists in allowing deviations in the unification conditions at M_{GUT} . For instance, deviations from universality in the scalar masses at M_{GUT} , which split M_{H_1} from M_{H_2} may be parametrized as $M_{H_i}^2(M_{GUT}) = m_0^2(1 + \delta_i)$. This is the case of non-universal SUGRA (nuSUGRA) that we considered in Refs. [12, 13, 19]. Further extensions of deviations from universality in SUGRA models which include squark and/or gaugino masses are discussed, for instance, in [15, 16].

More recently, the possibility that the initial scale for the RGE running, M_I , might be smaller than $M_{GUT} \sim 10^{16}$ has been raised, on the basis of a number of string models (see, for instance, [17, 20, 21] and references quoted therein). As is stressed in Ref.[20], M_I might be anywhere between the EW scale and the Planck scale, with significant consequences for the size of the neutralino–nucleon cross section.

3.2 Effective MSSM

The large uncertainties involved in the choice of the scale M_I make the SUGRA schemes somewhat problematic: the originally appealing feature of a universal SUGRA with few parameters fails, because of the need to take into consideration the variability of M_I or, alternatively, to add new parameters which quantify the various deviation effects from universality at the GUT scale. Thus, it appears more convenient to work with a phenomenological susy model whose parameters are defined directly at the electroweak scale. We denote here this effective scheme of MSSM by effMSSM. This provides, at the EW scale, a model, defined in terms of a minimum number of parameters: only those necessary to shape the essentials of the theoretical structure of an MSSM, and of its particle content. Once all experimental and theoretical constraints are implemented in this effMSSM model, one may investigate its compatibility with specific theoretical schemes at the desired M_I .

In the effMSSM scheme we consider here, we impose a set of assumptions at the electroweak scale: a) all trilinear parameters are set to zero except those of the third family, which are unified to a common value A ; b) all squark soft-mass parameters are

taken degenerate: $m_{\tilde{q}_i} \equiv m_{\tilde{q}}$; c) all slepton soft-mass parameters are taken degenerate: $m_{\tilde{l}_i} \equiv m_{\tilde{l}}$; d) the $U(1)$ and $SU(2)$ gaugino masses, M_1 and M_2 , are assumed to be linked by the usual relation $M_1 = (5/3) \tan^2 \theta_W M_2$ (this is the only GUT-induced relation we are using, since gaugino mass unification appears to be better motivated than scalar masses universality). As a consequence, the supersymmetric parameter space consists of seven independent parameters. We choose them to be: $M_2, \mu, \tan \beta, m_A, m_{\tilde{q}}, m_{\tilde{l}}, A$ and vary these parameters in the following ranges: $50 \text{ GeV} \leq M_2 \leq 1 \text{ TeV}$, $50 \text{ GeV} \leq |\mu| \leq 1 \text{ TeV}$, $80 \text{ GeV} \leq m_A \leq 1 \text{ TeV}$, $100 \text{ GeV} \leq m_{\tilde{q}}, m_{\tilde{l}} \leq 1 \text{ TeV}$, $-3 \leq A \leq +3$, $1 \leq \tan \beta \leq 55$ (m_A is the mass of the CP-odd neutral Higgs boson).

The effMSSM scheme proves very manageable for the susy phenomenology at the EW scale; as such, it has been frequently used in the literature in connection with relic neutralinos (often with the further assumption of slepton/squark mass degeneracy: $m_{\tilde{q}} = m_{\tilde{l}}$). Notice that here we are not assuming slepton/squark mass degeneracy.

We recall that even much larger extensions of the supersymmetric models could be envisaged: for instance, non-unification of the gaugino masses [16, 22], and schemes with CP-violating phases [23].

Here we only report results in the effective scheme at EW scale, except for a few comments on universal and non-universal SUGRA results in Sect. 4. For further details we refer to Refs. [2, 13].

The neutralino is defined as the lowest-mass linear superposition of photino ($\tilde{\gamma}$), zino (\tilde{Z}) and the two higgsino states ($\tilde{H}_1^\circ, \tilde{H}_2^\circ$): $\chi \equiv a_1 \tilde{\gamma} + a_2 \tilde{Z} + a_3 \tilde{H}_1^\circ + a_4 \tilde{H}_2^\circ$. Hereafter, the nature of the neutralino is classified in terms of a parameter P , defined as $P \equiv a_1^2 + a_2^2$. The neutralino is called a gaugino when $P > 0.9$, a higgsino when $P < 0.1$, mixed otherwise.

3.3 Constraints on supersymmetric parameters

In our exploration of the susy parameter space, we have implemented the following experimental constraints: accelerators data on supersymmetric and Higgs boson searches (CERN e^+e^- collider LEP2 [24] and Collider Detector CDF at Fermilab [25]); measurements of the $b \rightarrow s + \gamma$ decay [26].

The new measurement of the muon anomalous magnetic moment a_μ [27] was recently considered by a number of authors as a sign of supersymmetry. However, a deviation of the experimental value a_μ^{expt} from the SM evaluation never exceeded a mere 1.8σ , or even less [28], due the uncertainties affecting the evaluation of the hadronic contributions. Now, in the light of the recent clarification about the sign of the hadronic light-by-light contribution [29, 30], the putative deviation effect on a_μ is evaporating away. Thus, in our analysis we do not assume that the new determination of a_μ^{expt} is a sign of supersymmetry; we only use a_μ^{expt} as a constraint: the supersymmetric contribution to muon anomalous magnetic moment is set to be constrained in the range: $-200 \leq a_\mu^{susy} \cdot 10^{11} \leq 640$. To establish this interval, we have combined the results of Refs. [31, 32, 33] for the hadronic vacuum polarization contributions and Refs. [29, 30] for the hadronic light-by-

light contributions.

As we mentioned in the Introduction, we have not restricted our exploration of the supersymmetric parameter space by requiring the neutralino relic abundance $\Omega_\chi h^2$ to sit in any *a priori* chosen cosmological range. This will enable us to analyse our results in terms of relic neutralinos comprising either a dominant or a sub-dominant relic population.

4 Results and conclusions

In what follows we present some of our results in the framework of the effMSSM scheme. The evaluation of $\Omega_\chi h^2$ follows the procedure given in [34].

The cross-section $\sigma_{\text{scalar}}^{(\text{nucleon})}$ has been calculated with the formulae reported in Refs.[35]. Important entries in $\sigma_{\text{scalar}}^{(\text{nucleon})}$ are the quantities $m_q < N|\bar{q}q|N >$, where the quark scalar densities $\bar{q}q$ are averaged over the nucleonic state. The values of these quantities, derived from the pion-nucleon sigma term $\sigma_{\pi N}$ and other hadronic quantities, are affected by large uncertainties [35]. The quantity $m_s < N|\bar{s}s|N >$, which is the most important term among the $m_q < N|\bar{q}q|N >$'s unless $\tan\beta$ is very small [36], is affected by an uncertainty factor larger than 3. This conclusion is reinforced by the most recent determinations of $\sigma_{\pi N}$ [37, 38], as discussed in Ref. [39].

The results presented in Figs. 1–3 employ the following set of values for the quantities $m_q < N|\bar{q}q|N >$ (denoted as set 1 in Ref. [35]): $m_l < \bar{l}l > = 23$ MeV, $m_s < \bar{s}s > = 215$ MeV, $m_h < \bar{h}h > = 50$ MeV. For the reasons discussed above, all values concerning $\sigma_{\text{scalar}}^{(\text{nucleon})}$ in Figs. 1–3 are subject to an increase of ~ 4 , when the current uncertainties in the $m_q < N|\bar{q}q|N >$'s are taken into account.

Now let us turn to the presentation of our main results. In Fig.1 we give the scatter plot for $\sigma_{\text{scalar}}^{(\text{nucleon})}$ versus $\Omega_\chi h^2$. The two vertical lines denote the favorite range for $\Omega_m h^2$: $0.05 \leq \Omega_m h^2 \leq 0.3$. The two horizontal lines bracket the range of sensitivity in current WIMP direct experiments [40, 41], which, taking into account astrophysical uncertainties [42], turns out to be $4 \cdot 10^{-10} \text{ nbarn} \leq \xi \sigma_{\text{scalar}}^{(\text{nucleon})} \leq 2 \cdot 10^{-8} \text{ nbarn}$, for WIMP masses in the interval $40 \text{ GeV} \leq m_W \leq 200 \text{ GeV}$. Fig.1 shows that the present experimental sensitivity in WIMP direct searches allows the exploration of supersymmetric configurations compatible with current accelerator bounds; a number of configurations stay inside the region of cosmological interest.

Once a measurement of the quantity $\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}$ is performed, values for the local density ρ_χ versus the relic abundance $\Omega_\chi h^2$ may be deduced by proceeding in the following way [35]: 1) ρ_χ is evaluated as $[\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}]_{\text{expt}} / \sigma_{\text{scalar}}^{(\text{nucleon})}$, where $[\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}]_{\text{expt}}$ denotes the experimental value, and $\sigma_{\text{scalar}}^{(\text{nucleon})}$ is calculated as indicated above; 2) to each value of ρ_χ one associates the corresponding calculated value of $\Omega_\chi h^2$. The scatter plot in Fig.2 is derived for the representative value $[\rho_\chi / (0.3 \text{ GeV cm}^{-3}) \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}]_{\text{expt}} = 1 \cdot 10^{-9} \text{ nbarn}$ within the annual-modulation region of Ref. [41], and by taking m_χ in the range $40 \text{ GeV} \leq m_W \leq 200 \text{ GeV}$.

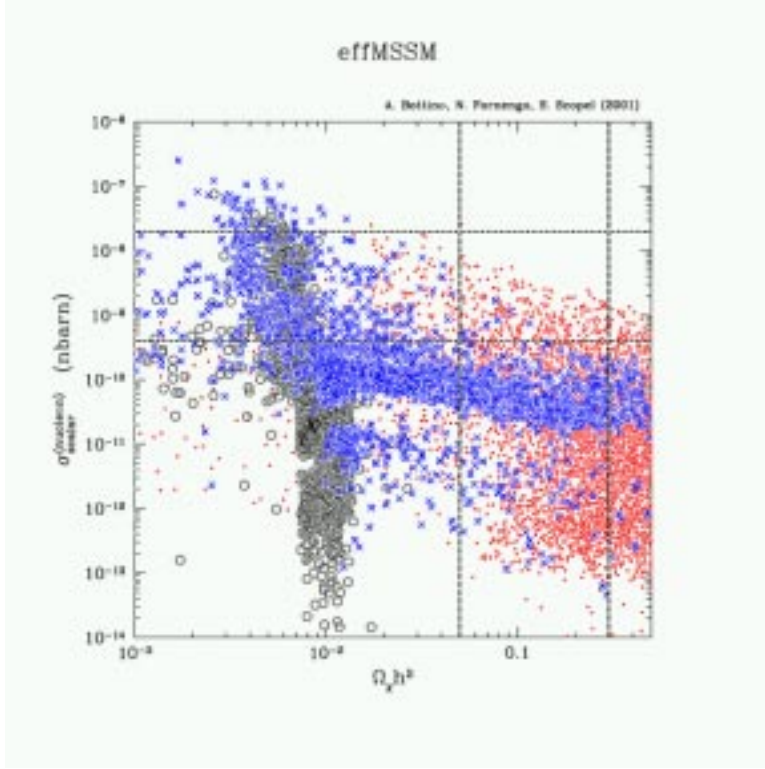


Figure 1: Scatter plot of $\sigma_{\text{scalar}}^{(\text{nucleon})}$ versus $\Omega_\chi h^2$. m_χ is taken in the interval $40 \text{ GeV} \leq m_W \leq 200 \text{ GeV}$. The two horizontal lines bracket the sensitivity in current WIMP direct experiments $4 \cdot 10^{-10} \text{ nbarn} \leq \xi \sigma_{\text{scalar}}^{(\text{nucleon})} \leq 2 \cdot 10^{-8} \text{ nbarn}$, for $\xi = 1$. The two vertical lines denote the range $0.05 \leq \Omega_m h^2 \leq 0.3$. Dots (crosses) denote gaugino (mixed) configurations.

The plot of Fig.2 shows that the most interesting region, *i.e.* the one with $0.2 \text{ GeV cm}^{-3} \leq \rho_\chi \leq 0.7 \text{ GeV cm}^{-3}$ and $0.05 \leq \Omega_m h^2 \leq 0.3$ (cross-hatched region in the figure), is covered by susy configurations probed by the WIMP direct detection. Let us examine the various sectors of Fig.2. Configurations above the upper horizontal line are incompatible with the upper limit on the local density of dark matter in our Galaxy and must be disregarded. Configurations above the upper slanted dot-dashed line and below the upper horizontal solid line would imply a stronger clustering of neutralinos in our halo as compared to their average distribution in the Universe. This situation may be considered unlikely, since in this case neutralinos could fulfill the experimental range for ρ_χ , but they would contribute only a small fraction to the cosmological cold dark matter content. For configurations which fall inside the band delimited by the slanted dot-dashed lines and simply-hatched in the figure, the neutralino would provide only a fraction of the cold dark matter at the level of local density and of the average relic abundance, a situation which would be possible, for instance, if the neutralino is not the unique cold dark matter

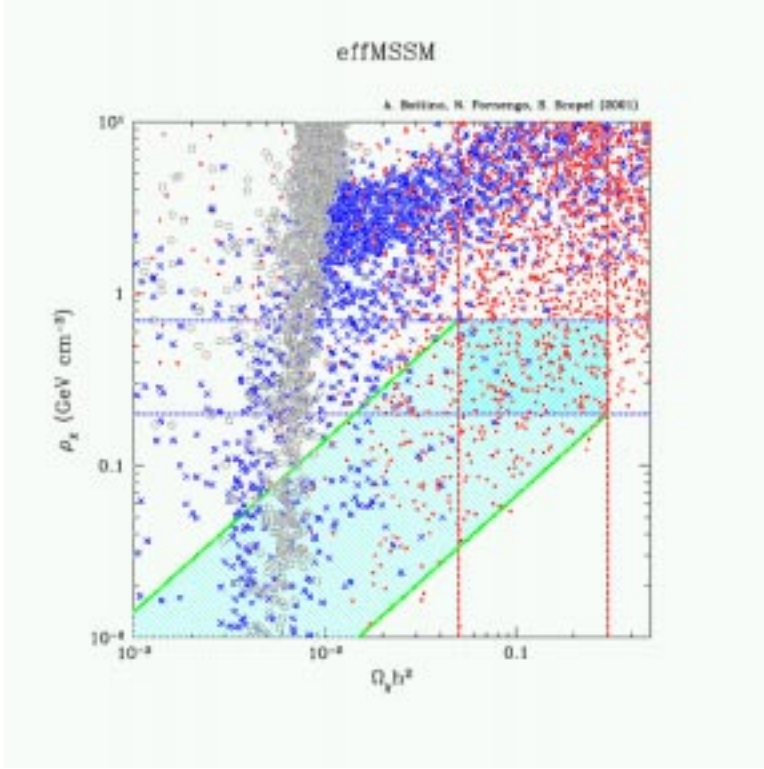


Figure 2: Scatter plot of ρ_χ versus $\Omega_\chi h^2$. This plot is derived from the experimental value $[\rho_\chi / (0.3 \text{ GeV cm}^{-3}) \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}]_{\text{expt}} = 1 \cdot 10^{-9} \text{ nbarn}$ and by taking m_χ in the interval $40 \text{ GeV} \leq m_\chi \leq 200 \text{ GeV}$, according to the procedure outlined in the text. The two horizontal lines delimit the range $0.2 \text{ GeV cm}^{-3} \leq \rho_\chi \leq 0.7 \text{ GeV cm}^{-3}$; the two vertical ones delimit the range $0.05 \leq \Omega_\chi h^2 \leq 0.3$. The band delimited by the two slanted dot-dashed lines and simply hatched is the region where rescaling of ρ_l applies. Dots denote gauginos, circles denote higgsinos and crosses denote mixed configurations.

particle component. To neutralinos belonging to these configurations one should assign a *rescaled* local density.

We remind that the scatter plot in Fig.2 refers to a representative value of $[\rho_\chi \cdot \sigma_{\text{scalar}}^{(\text{nucleon})}]$ inside the current experimental sensitivity region, thus the plot in Fig.2 shows that current experiments of WIMP direct detection are probing relic neutralinos which may reach values of cosmological interest, but also neutralinos whose local and cosmological densities may provide only a very small fraction of these densities.

In Fig.3 we give the scatter plot for the quantity $\xi \sigma_{\text{scalar}}^{(\text{nucleon})}$ versus m_χ . The solid line denotes the frontier of the 3σ annual-modulation region of Ref.[41], when only the uncertainties in ρ_l and in the dispersion velocity of a Maxwell-Boltzmann distribution, but not the ones in other astrophysical quantities, are taken into account. Effects due to a possible bulk rotation of the dark halo or to an asymmetry in the WIMP velocity

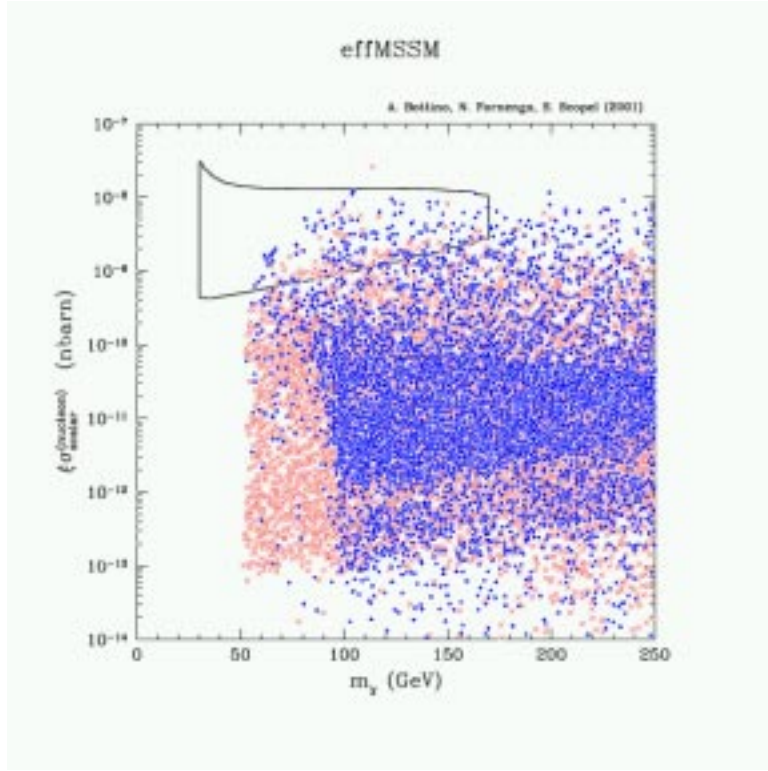


Figure 3: Scatter plot of $\xi\sigma_{\text{scalar}}^{(\text{nucleon})}$ versus m_χ . Crosses (dots) denote configurations with $\Omega_\chi h^2 > 0.05$ ($\Omega_\chi h^2 < 0.05$). The solid contour denotes the 3σ annual-modulation region of Ref.[41] (with the specifications given in the text).

distribution would move this boundary towards higher values of m_χ [42]. Our results in Fig.3 show that the susy scatter plot reaches up the annual-modulation region of Ref.[41].

In our figures only results referring to the effMSSM scheme are reported. For comparisons among results in various schemes: universal SUGRA, non-universal SUGRA and effMSSM, we refer to Refs. [2, 13]. As for the universal SUGRA, we only wish to remark that this very constrained model, combined with the present rather stringent experimental bounds from LEP2, typically entails a sizeable suppression of the neutralino-nucleon cross-section. Whether or not this suppression may prevent the calculated $\sigma_{\text{scalar}}^{(\text{nucleon})}$ from reaching the region of present experimental sensitivity does depend on how the various constraints (typically the bounds on Higgs masses, on m_t and m_b) are implemented in the evaluations. By way of example, it is worth mentioning that the explicit bounds on the quantity $\sin^2(\alpha - \beta)$ (α being the Higgs mixing angle in the neutral CP-even Higgs sector) as a function of m_h should be taken into account, rather than using a flat lower bound of 115 GeV for m_h [8, 9]. Neglecting these features in a SUGRA calculation may lead to biased conclusions.

We now summarize the main points of this paper:

- Most recent theoretical developments suggest supersymmetric schemes which notably differ from a strict model such as the universal SUGRA and point to the fact that this constrained scheme should be relaxed in many instances. Here, we have employed an effective MSSM scheme at the electroweak scale, which is particularly convenient to treat the relic neutralino phenomenology.
- We have shown that current direct experiments for WIMPs, when interpreted in terms of relic neutralinos, are indeed probing regions of supersymmetric parameter space compatible with all present experimental bounds.
- We have proved that part of the configurations probed by current WIMP experiments entail relic neutralinos of cosmological interest, and, *a fortiori* also neutralinos which might comprise only a fraction of the required amount of dark matter in the Universe.

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